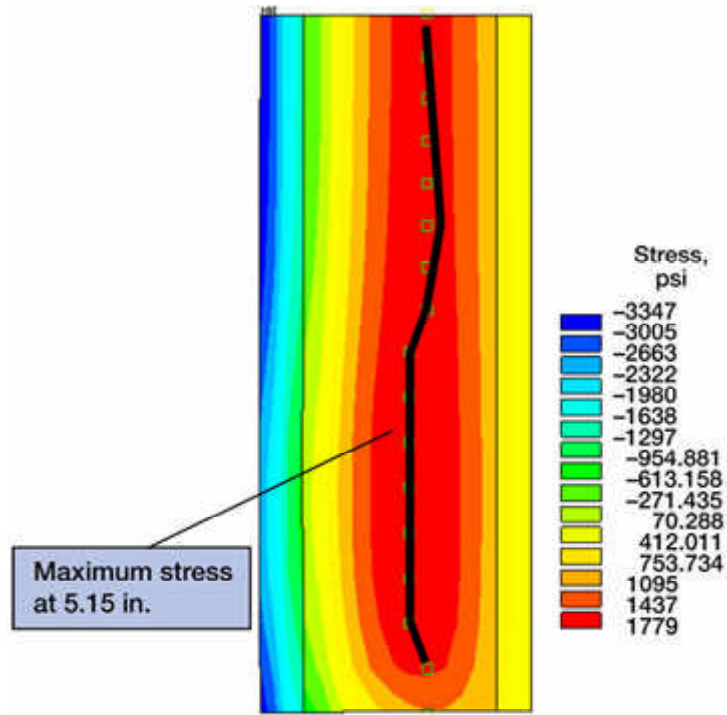


# **Integrated Nondestructive Evaluation and Finite Element Analysis Predicts Crack Location and Shape**

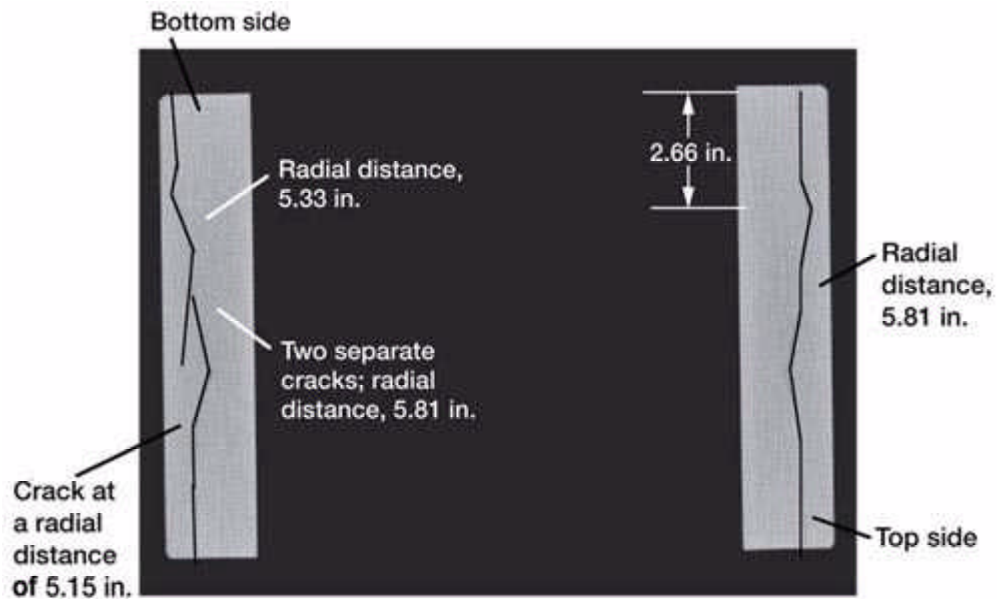
Composite flywheels are being developed as an alternative to expensive, short-life chemical batteries. Flywheels promise orders of magnitude increases in performance and service life in many NASA and military applications—including spacecraft, launch vehicles, aircraft power systems, uninterruptible power supplies, and planetary outposts and rovers (ref. 1). Although the technology holds great promise, there remain a number of challenges to overcome (such as rotor certification for safe life) before these advanced flywheels reach operational status. Carbon-fiber-reinforced polymer composites are the materials of choice for energy applications because of the high energy and power densities that they can achieve (ref. 2). Flywheel design topology can also allow a burst failure mode that is relatively benign in comparison with flywheels made of metallic materials (ref. 3).

A successful deployment of flywheels must address the long-term durability issue of polymer composites because of the limited availability of their fatigue characteristics and nonlinear behavior especially at elevated temperatures. Nondestructive evaluation (NDE) combined with structural analysis tools is being used at the NASA Glenn Research Center to accurately assess the applicability of using various composite materials to design a suitable rotor/flywheel assembly. However, for NDE information to be useful in structural characterization and modeling, the NDE data format must be compatible with microstructural and structural models currently being developed (ref. 4).

This study describes the finite-element analyses and the NDE modality undertaken on two flywheel rotors that were spun to burst speed. Computed tomography and dimensional measurements were used to nondestructively evaluate the rotors before and/or after they were spun to the first crack detection. Computed tomography data findings of two- and three-dimensional crack formation were used to conduct finite-element (FEA) and fracture mechanics analyses (ref.5). A procedure to extend these analyses to estimate the life of these components is also outlined. NDE-FEA results for one of the rotors are presented in the figures. The stress results in the top figure, which represent the radial stresses in the rim, clearly indicate that the maximum stress region is within the section defined by the computed tomography scan. Furthermore, the NDE data correlate well with the FEA results, since the crack at the bottom of the figure on the right closely follows the radial stress distribution shown in the figure on the left. In addition, the measurements reported, as obtained from the figure on the right, show that the NDE and FEA data are in parallel. Details pertaining to this study are more fully described in reference 6.



*Rim radial stress distribution at 34,000 rpm for the rotor-B 30 slice (ring midplane cross section) based on ANSYS three-dimensional, finite element analysis.*



*Cross-sectional computed tomography scan of rotor B showing cracking.*

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**CSU contact:** Dr. Ali Abdul-Aziz, 216-433-6729, Ali.Abdul-Aziz@grc.nasa.gov

**Glenn contacts:** Dr. George Y. Baaklini, 216-433-6016, George.Y.Baaklini@grc.nasa.gov; and Jeffrey J. Trudell, 216-433-5303, Jeffrey.J.Trudell@grc.nasa.gov

**Authors:** Dr. Ali Abdul-Aziz, Dr. George Y. Baaklini, and Jeffrey J. Trudell

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